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Original article

Aerobic capacity and hematological response to exercise: A study on school-going regularly exercising boys in two different air pollution zones

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Abstract

Background/Objective: The purpose of this study was to evaluate the effects of exercise on aerobic power and hematological profile among trained school-going boys in an environment with similar climatic characteristics but different concentrations of air pollutants.
Methods: This trial comprised 40 school-going trained boys (age range 14–16 years) from West Bengal, India. Two places with similar climatic conditions (altitude, temperature, and humidity), but low and high concentrations of air pollutants were selected. Height and weight of all the participants were measured. Participants underwent a shuttle run test for assessment of aerobic capacity (VO_{2max}) in both areas after a 1-week gap. Venous blood sample was drawn from the cubital vein immediately after completion of the shuttle run test and red blood cell (RBC) count, white blood cell (WBC) count, packed cell volume (PCV), hemoglobin (Hb) concentration, mean corpuscular volume (MCV), and mean corpuscular hemoglobin concentration (MCHC) were determined by standard methods. Measured parameters were compared between the two areas.
Results: Compared with the area having low pollution levels, we obtained significantly lower value in mean VO_{2max}, RBC count, Hb, PCV, and MCHC, but significantly higher value in WBC count and MCV in the area with high pollution levels. Performing exercise in high-polluted air may lead to a significant reduction in the performance level of school-going trained boys.
Conclusion: The study findings suggest that air pollution could have negative effects on the hematological profile of boys and longitudinal studies may be carried out for assessing its clinical importance.

Keywords: Aerobic power; Air pollution; Hematology; Trained boys

Introduction

One of the serious problems that the world is facing nowadays is environmental pollution, which is increasing with every passing year and causing severe and irreparable damage. There is increasing evidence about the harmful effects of air pollution, which can affect human health in both short term and long term. A series of major epidemiologic and observational studies have revealed adverse effects of air pollution on cardiovascular health and fitness.[1–4] Morbidity and mortality attributable to air pollution continue to be a growing public health concern worldwide. Different groups of individuals may be affected in different ways, and some people are more vulnerable to air pollution than others.

While aerobic activity is one of the keys to a healthy lifestyle, air pollution and exercise can be an unhealthy combination. The environment we exercise in, particularly the air quality, is just as important as the exercise itself.

The level to which an individual is affected by air pollution generally depends on the extent of exposure to destructive

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pollutants, which is usually determined by total time of exposure and chemical's concentration. Both controlled human studies and observational studies have reported that air pollution adversely affects athletic performance during both training and competition.[5] Exposure to air pollution is considered a concern for the general population as well, but because air intake of athletes is higher, the athletic population looks more susceptible to high concentrations of outdoor air pollutants. A recent study in Kolkata by Chatterjee and Das[6] revealed the effect of increasing atmospheric pollution on lung function and possible negative stress of increasingly sedentary lifestyles. A study by Das and Chatterjee[7] revealed that environmental air pollutants might have an adverse effect on pulmonary function irrespective of whether the boys were undergoing regular physical training or not. Das et al[8] also showed that one of the physical fitness components of exercising population in less pollutant zones was significantly higher than their counterparts from highly polluted zones in West Bengal, India. However, studies on the effect of pollution on cardiovascular fitness and hematological profile in exercising young population in India are rare.

Considering all these aspects, this study was designed with the goal to determine whether there are differences in blood markers and aerobic capacity after a single bout of exercise performed in areas with different concentrations of air pollutants. The purpose of this study was to evaluate the effects of exercise on the aerobic power and hematological parameters among school-going trained boys (age range 14−16 years) in environments with similar climatic conditions but different concentrations of air pollutants.

Methods

Participants

This trial consisted of 40 school-going boys (age range 14−16 years). Eligibility criteria were being apparently healthy, nonsmoker, and participating in physical training sessions (sprint) for at least three times a week, and having no history of any chronic medication use and acute or chronic diseases. All institutional policies concerning the involvement of human participants in research were followed. Ethical approval was obtained from the authority concerned.

Place selection

Two zones, namely, Tollygunge and Sonarpur in West Bengal, India, were selected for this study. Tollygunge is a part of core Kolkata, which was included in the city of Kolkata (core) in 1951 (Kolkata proper).[9,10] The other area is Sonarpur, a rural−urban fringe in the city of Kolkata that was recently categorized by the Kolkata Metropolitan Development Authority as a “Growth Centre”.[11]

Air quality of these two zones was monitored for 24 hours during winter for a 3-month period from November 1, 2012, to January 31, 2013, and concentrations of suspended particulate matter (SPM), respirable particulate matter (RPM), sulfur dioxide (SO_2), and oxides of nitrogen as nitrogen dioxide (NO_2) were assessed by standard procedures described in the following section. Average concentrations [mean ± standard deviation (SD)] of air pollutants were then used for analysis.

Equipment used for ambient air-quality monitoring

For monitoring, the following equipment was used: (1) respirable dust sampler (APM 460) and (2) gas-absorbing glass impingers. For analysis, the following equipment was used: (1) spectrophotometer (Spectronic GENESYS), (2) single pan balance (Mettler), (3) oven; and (4) desiccator.

Ambient air-quality monitoring methodology

SPM and RPM

The APM 460 sampler first separates coarse particles (>10 μm) from the airstream before filtering it on the 0.5-μm pore-size filter, thereby allowing measurement of both SPM[12] and respirable fraction of the SPM (i.e., RPM[13]).

The mass concentration of PM can be calculated using the following equation and reported to the nearest microgram/cubic meter (μg/m^3).

$$\mathrm{PM}\ \left(\mu g/m^3\right) = \frac{(\mathrm{W2} - \mathrm{W1}) \times 10^6}{\mathrm{V}} \tag{1}$$

where PM = mass concentration of particulate matter (μg/m^3), W1 = initial weight of filter paper (g), W2 = final weight of exposed filter papers (g), V = air volume sampled (m^3), and 10^6 = conversion factor from grams to micrograms.

Sulfur dioxide

When sulfur dioxide (SO_2) from the airstream is absorbed in a solution of sodium tetrachloromercurate at a rate of 0.3 liter/min (LPM) or 0.5 LPM, dichlorosulphitomercurate is formed, which is a stable compound. The amount of SO_2 is then estimated by the color produced when *p*-rosaniline hydrochloride is added to the solution.[14] The color is estimated by a reading from a spectrophotometer for which a calibration curve is prepared.

$$\mathrm{SO_2}\ \left(\mu g/m^3\right) = \frac{\text{Microgram of } \mathrm{SO_2} \text{ from curve } \times 25 \times 1000}{10 \times \text{hour} \times 60 \times \text{LPM}} \tag{2}$$

Oxides of nitrogen

Oxides of nitrogen (NO_x) are collected by bubbling air through an NaOH solution at a rate of 0.4 LPM to form a stable solution of sodium nitrate. The nitrate ion produced during sampling is determined spectrophotometrically by treating the exposed absorbing reagent with phosphoric acid, sulfanilamide, and *N*-(1-naphthyl)ethylenediamine dihydrochloride.[15]

$$\mathrm{NO}_x\ \left(\mu g/m^3\right) = \frac{\text{Microgram of } \mathrm{NO}_x \text{ from curve } \times 25 \times 1000}{10 \times \text{hour} \times 60 \times \text{LPM} \times 0.82} \tag{3}$$

Data collection

Participants underwent a shuttle run test for assessment of aerobic capacity in both areas after a 1-week gap. Venous blood sample was drawn from the cubital vein immediately after the completion of shuttle run test and red blood cell (RBC) count, white blood cell (WBC) count, packed cell volume (PCV), hemoglobin (Hb) concentration, mean corpuscular volume (MCV), and mean corpuscular hemoglobin concentration (MCHC) were determined by standard methods. Age of participants was calculated from the birth date. Standing height in centimeter was measured with shoes removed, feet together. Weight in kilogram was measured with shoes and jackets removed.

Prediction of maximum oxygen uptake using the 20-m multistage shuttle run test

Participants started running back and forth on a 20-m course and touched the 20-m line at an initial speed of 8.5 km/h. The running speed got progressively faster (0.5 km/h every minute), in accordance with the pace dictated by a sound signal on an audiotape. Several shuttle runs made up each stage, and participants were instructed to keep pace with the signal for as long as possible. When participants could no longer keep pace with the signal, the last stage announced was used to predict maximum oxygen uptake (VO_{2max}) using the equation proposed by Chatterjee et al[16] for junior sprinters.

$$Y = 2.36 + 5.62X - 1.38A \tag{4}$$

where: $Y = VO_{2max}$ (mL/kg/min), X = maximal shuttle run speed (km/h), and A = age (year).

Participants were asked not to participate in any physical activity session 24 hours before the test, which was conducted in the morning (between 9 AM and 11 AM) in the area with low pollution level, and after a 7-day interval, it was repeated in the area with high pollution level. The whole experiment was performed at a temperature between 22°C and 24°C and with relative humidity ranging between 70% and 80% for both areas. Hematological tests were conducted after completing the physical activity sessions.

Estimation of hematological profiles

Collection of blood sample

Immediately after the shuttle run test, venous blood samples were drawn from the cubital vein according to the guidelines of the International Federation of Clinical Chemistry.[17] Blood samples were taken in tubes containing EDTA (tripotassium salt) and were analyzed on the same day.

The RBC and WBC count, hematocrit/PCV, and Hb concentration were measured using a Neubauer hemocytometer[18,19] (Neubauer *Precicolor HBG Germany)*, a Wintrobe tube[19] (Wintrobe Tube Full Calib 200/Bx-64FR828B), and by calculating the levels of cyanomethemoglobin,[20] respectively. The MCV and MCHC were determined using the following equations[19]:

$$\mathrm{MCV}(\mathrm{cu}\mu) = \mathrm{PCV}(\mathrm{mL/Lofblood})/\mathrm{RBCcount}(\mathrm{millions/mm^3ofblood}) \tag{5}$$

$$\mathrm{MCHC}(\%) = [\mathrm{hemoglobinconcentration}(\mathrm{g/dL}) \times 100]/\mathrm{PCVin100\ mLofblood} \tag{6}$$

Statistical analysis

All values are expressed as mean ± SD. SPSS version 20 (SPSS Inc., Chicago, IL, USA) was used for analysis. Paired *t* tests were adopted for statistical analysis of the data.

Results

The height and weight of the participants (mean ± SD) were 157.82 ± 4.56 cm and 43.08 ± 3.85 kg, respectively. The mean ± SD of ambient air-quality data given in Table 1 indicates that all air-quality parameters (SPM, RPM, SO_2, and NO_x) were significantly higher in Tollygunge than in Sonarpur. Therefore, the former was selected as the high-polluted area, and the latter as the less-polluted area in this study. The mean ± SD of VO_{2max} and hematological profiles and the comparison of differences in variables after exercise in areas with high and low air pollution levels listed in Table 2 indicated a significantly lower value in mean VO_{2max}, RBC count, Hb, PCV, and MCHC, but a significantly higher value in WBC count and MCV in the high-polluted area than in the less-polluted area.

Discussion

This study assessed the effects of performing exercise on aerobic power and hematological profiles in areas with low

Table 1
Differences in air pollutant concentrations between locations.

Air pollutant	Tollygunge	Sonarpur	p
SPM (μg/m^3)	269.85 ± 54.76	81.58 ± 18.28	<0.01
RPM (μg/m^3)	154.08 ± 44.72	33.28 ± 10.17	<0.01
SO_2 (μg/m^3)	11.54 ± 3.98	0.64 ± 1.53	<0.01
NO_x (μg/m^3)	86.77 ± 17.30	10.03 ± 5.28	<0.01

Data are presented as mean ± SD.
RPM = respirable particulate matter; SD = standard deviation; SPM = suspended particulate matter.

Table 2
Comparison of changes in variables after exercise in high and low pollution areas.

Parameters	Tollygunge	Sonarpur	p
VO_{2max} (mL/kg/min)	50.32 ± 3.05	53.91 ± 2.82	<0.05
RBC count (million/mm^3)	4.29 ± 0.50	5.01 ± 0.53	<0.05
PCV (%)	42.60 ± 2.46	45.50 ± 3.01	<0.05
Hb concentration (g%)	13.01 ± 0.65	13.60 ± 0.61	<0.05
WBC count (×10^3/μL)	9.98 ± 1.77	8.25 ± 1.90	<0.05
MCV (cu μ)	85.87 ± 4.81	82.87 ± 4.77	<0.05
MCHC (%)	32.40 ± 3.23	34.93 ± 3.19	<0.05

Data are presented as mean ± SD.
MCHC = mean corpuscular hemoglobin concentration; MCV = mean corpuscular volume; PCV = packed cell volume; RBC = red blood cell; SD = standard deviation; WBC = white blood cell.

and high concentrations of air pollutants among trained individuals. However, the study was limited to a specific age group and nonsmoking participants only. In this study, we made an attempt to determine whether there are differences in the aerobic capacity and hematological profile after a single bout of exercise performed in an area with high pollution and another area with low pollution levels. The study findings show that performing exercise in an area with high pollution levels resulted in a significantly lower value for aerobic capacity and poor hematological profile. Previous studies carried out on health effects of air pollution revealed the risk of acquiring cardiovascular and respiratory diseases.[21,22] Ambient air pollution, especially PM, has been recognized as a hazard to cardiovascular health.[23,24] The results of this study demonstrated a significantly lower value for aerobic capacity after a physical exertion in a highly polluted area, which illustrates that endurance performance is adversely affected by polluted air. This is reported to be associated with an impaired oxygen distribution function and pulmonary dysfunction while performing exercise in polluted air.[25,26] According to Yu et al,[27] air pollution adversely affected VO_{2max} in children, and physical exercise in a polluted environment might not have beneficial effect on cardiopulmonary fitness.

This investigation has shown that exposure to high levels of air pollutants is associated with poor hematological profile among active individuals. Significantly lower value in RBC count, Hb, PCV, and MCHC after exercise in high polluted air might be due to small increase in blood volume upon exposure to higher air pollutant levels, as documented in a previous experimental study.[28] In addition, findings regarding the effects of acute exposure to air pollutants on WBC count in active school-going boys supported the previous population-based study conducted among people aged 20–89 years, which revealed a statistically significant association between WBC count and estimated local particulate matter 10 μm (PM_{10}) levels; additionally, participants from the least polluted areas in that study had lower WBC counts than the others. Short-term elevation of ambient PM is associated with increased levels of inflammatory markers such as WBC count.[29,30] This increase in WBC count following exposure to high concentrations of air pollutants might be due to their tissue-damaging effects and rise of antibody production in response to the exposure. The results of this study are similar to those reported by Jacobs et al,[31] who reported that the percentage of blood neutrophils increased significantly more after cycling on the road than cycling in a clean room with filtered air. Previous studies[32,33] reported an association between increase in long-term cardiovascular risks and high WBC count. These changes might have occurred due to strengthening of immune system to reduce the effect of pollutants inhaled. A study by Seaton et al[34] determined the relationship between exposure to PM, measured as PM_{10}, and changes in Hb concentration, PCV. Athletes are at special risk of inhaling pollutants because during exercise, with increase in minute ventilation, there is a proportionate increase in the quantity of pollutants inhaled (V_E); additionally, a large fraction of air is inhaled through the mouth during exercise, effectively bypassing the normal nasal mechanisms for the filtration of large particles and soluble vapors.[35]

In conclusion, performing exercise in high-polluted air may lead to a significant reduction in the performance level of school-going trained boys. This finding suggests that air pollution could have negative effects on the hematological profile of trained boys. Keeping in view the clinical importance, this particular area needs further research and extensive investigation through longitudinal studies.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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References

1. Dockery DW, Pope 3rd CA, Xu X, et al. An association between air pollution and mortality in six U.S. cities. *N Engl J Med*. 1993;329:1753–1759.
2. Pope 3rd CA, Burnett RT, Thurston GD, et al. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation*. 2004;109:71–77.
3. Miller KA, Siscovick DS, Sheppard L, et al. Long-term exposure to air pollution and incidence of cardiovascular events in women. *N Engl J Med*. 2007;356:447–458.
4. Hoek G, Brunekreef B, Goldbohm S. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. *Lancet*. 2002;360:1203–1209.
5. Pierson WE, Covert DS, Koenig JQ, et al. Implications of air pollution effects on athletic performance. *Med Sci Sports Exerc*. 1986;18:322–327.
6. Chatterjee P, Das P. Changes in lung function status of adult female over last one decade: a cross-sectional study in Kolkata, India. *Int Res J Environ Sci*. 2013;2:1–5.
7. Das P, Chatterjee P. Association of ambient air quality with pulmonary function of youngster footballers. *Asian J Sports Med*. 2014;5:39–46.

8. Das P, Debnath P, Chatterjee P, et al. Study of selected motor ability variables of school going boys in two different pollutant zones. *Biomedicine*. 2005;25:21–26.
9. Munsi SK. *Calcutta Metropolitan Explosion: Its Nature and Roots*. New Delhi, India: People's Publishing House; 1975:74.
10. Chaudhuri S. *Calcutta, The Living City: The Present and Future. An Article by Chakraborty, S.C. The Growth of Calcutta in the Twentieth Century*. New York, NY: Oxford University Press; 1990:1–14.
11. Kolkata Metropolitan Development Authority. *Vision 2025 At a Glance. Perspective Plan of C.M.A. 2025*. Salt Lake, Kolkata: Kolkata Metropolitan Development Authority; 2000:25.
12. Central Pollution Control Board. *Central Laboratory Test Method, Document Number CB/CL/TM/9/C-3*. Delhi, India: Central Pollution Control Board; 2001.
13. Central Pollution Control Board. *Central Laboratory Test Method, Document Number CB/CL/TM/9/C-4*. Delhi, India: Central Pollution Control Board; 2001.
14. Central Pollution Control Board. *Central Laboratory Test Method, Document Number CB/CL/TM/9/C-6*. Delhi, India: Central Pollution Control Board; 2001.
15. Central Pollution Control Board. *Central Laboratory Test Method, Document Number CB/CL/TM/9/C-9*. Delhi, India: Central Pollution Control Board; 2001.
16. Chatterjee P, Banerjee AK, Das P, et al. Regression equations to predict VO_{2max} in untrained boys and junior sprinters of Kolkata. *J Exerc Sci Physiother*. 2008;04:104–108.
17. IFCC. The theory of reference values. Part 3. Preparation of individuals and execution of blood specimen collection for the production of reference and observed values. *Clin Chim Acta*. 1984;139:203F–230F.
18. Dacie JV, Lewis SM. *Practical Hematology*. 6th ed. New York, NY: Churchill Livingstone; 1984.
19. Chattopadhyay P. *Practical Physiology*. Kolkata, India: New Central Book Agency (P) Ltd; 2011.
20. Drabkin DL, Austin JH. Determination of haemoglobin in blood cyanomethaemoglobin method. *J Biol Chem*. 1935;112:51–53.
21. Tsai SS, Chang CC, Liou SH, et al. The effects of fine particulate air pollution on daily mortality: a case-crossover study in a subtropical city, Taipei, Taiwan. *Int J Environ Res Public Health*. 2014;11:5081–5093.
22. Rashidi M, Ramesht MH, Zohary M, et al. Relation of air pollution with epidemiology of respiratory diseases in isfahan, Iran from 2005 to 2009. *J Res Med Sci*. 2013;18:1074–1079.
23. Kaiser J. Epidemiology. Mounting evidence indicts fine-particle pollution. *Science*. 2005;307:1858–1861.
24. Atmosphere Nel A. Air pollution-related illness: effects of particles. *Science*. 2005;308:804–806.
25. Williams C. Environmental factors affecting elite young athletes. *Med Sport Sci*. 2011;56:150–170.
26. Rodriguez C, Tonkin R, Heyworth J, et al. The relationship between outdoor air quality and respiratory symptoms in young children. *Int J Environ Health Res*. 2007;17:351–360.
27. Yu IT, Wong TW, Liu HJ. Impact of air pollution on cardiopulmonary fitness in schoolchildren. *J Occup Environ Med*. 2004;46:946–952.
28. Davidson SB, Penney DG. Time course of blood volume change with carbon monoxide inhalation and its contribution to the overall cardiovascular response. *Arch Toxicol*. 1988;61:306–313.
29. Liao D, Heiss G, Chinchilli VM, et al. Association of criteria pollutants with plasma hemostatic/inflammatory markers: a population-based study. *J Expo Anal Environ Epidemiol*. 2005;15:319–328.
30. Schwartz J. Air pollution and blood markers of cardiovascular risk. *Environ Health Perspect*. 2001;109:405–409.
31. Jacobs L, Nawrot TS, de Geus B, et al. Subclinical responses in healthy cyclists briefly exposed to traffic-related air pollution: an intervention study. *Environ Health*. 2010;9:64.
32. Kannel WB, Anderson K, Wilson PW. White blood cell count and cardiovascular disease. Insights from the Framingham Study. *JAMA*. 1992;267:1253–1256.
33. Lee CD, Folsom AR, Nieto FJ, et al. White blood cell count and incidence of coronary heart disease and ischemic stroke and mortality from cardiovascular disease in African-American and white men and women: atherosclerosis risk in communities study. *Am J Epidemiol*. 2001;154:758–764.
34. Seaton A, Soutar A, Crawford V, et al. Particulate air pollution and the blood. *Thorax*. 1999;54:1027–1032.
35. McCafferty WB. *Air Pollution and Athletic Performance*. Springfield, IL: Charles C Thomas; 1981.